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Report No. 8926-168

Material - Adhesive Fiberglass Cloth to Metal Attaching

Screening Evaluations

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Material - Adhesive Fiberglass Cloth to Metal Attaching

Screening Evaluations

Abstract:

Thirty-two formulations of adhesive materials containing epoxy, polyester, polysulfide, polyamide, polyurethane or phenolic resins were screened by means of peel tests and bend tested to determine their possible utility for attaching fiberglass cloth to metal at room and elevated temperatures. Fourteen of these formulations were promising for room temperature application and ten were promising for elevated temperature (cured) application.

Reference: Hunt, H. H., Jenkins, R. W., Picotte, G. L., Sutherland, W. M., "Bonding of Structural Fiberglass Cloth Laminates to Metal," General Dynamics/Convair Report MP 56-309, San Diego, California, 29 March 1957. (Reference attached).

ENGINEERING TEST LABORATORIES

CONVAIR

A DIVISION OF GENERAL DYNAMICS CORPORATION

SAN DIEGO

REPORT 56-309

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(MRS 56-188)

TITLE

REPORT NO. 56-309
BONDING OF STRUCTURAL FIBER GLASS
CLOTH LAMINATES TO METAL

(MRS 56-188)

MODEL ALL

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REPORT NO. 56-309
BONDING OF STRUCTURAL FIBER GLASS CLOTH LAMINATES TO METAL

INTRODUCTION:

Exact information on the properties and possibilities of laminates is required for their effieient use in aircraft. While the basic types of polymers are not numerous, the number of compounds of resins available and in production is very large. A first step toward the effective use of these materials therefore is to define principle uses anticipated and select a limited number for more extensive testing.

OBJECT:

To screen resins available and methods of application for laminating fiberglass, cloth to sheet aluminum for selection of methods and materials of probable value for the following uses:

a. Dampening flutter and vibration in sheet aluminum to reduce fatigue damage.

b. Dampening sonic vibration.

c. Thermal barriers.

d. Protection of metal surfaces from corrosion and erosion.

CONCLUSIONS:

The formulations 2-5, 7-10, 14-16, 19, 21, 22 listed in Table I are promising materials with room temperature cures where service temperatures are not expected to exceed 150° F. for a., b., and d. The formulations from 23 to 32 with high temperature cures appear to be more suitable where higher temperatures are expeeted.

TEST SPECIMENS:

Laminated panels 0.050" x 20" were manufactured for this test by Department 49 (Production Plastics), Plant I, Convair San Diego. The aluminum sheet used was 7075-T6 bare 0.025" in thickness factory cleaned prior to fabrication with the sodium dichromate—sulfuric acid etch. Each panel had two layers of Volan 181 A glass cloth bonded to one aluminum surface with the appropriate resin.

Peel test strips one inch wide and conical mandrel test strips three inches wide were cut from these panels.

TEST PROCEDURE:

Drum peel tests on three specimens from each panel were made on the peel test machine in the Engineering Test Laboratory, Convair, San Diego and the average peel strength recorded. Compression and expansion bend tests were made on a 1.5" - .25" dia. conical mandrel on two to three specimens from each panel and the damage recorded. (See Table II). The above tests were all at room temperature.

Ruffer box tests, 0-17 psi, 10 cycles/min., 6" x 6" opening, 1/8" center deflection. 10,000 cycles at room temperature followed by 10,000 cycles at -65°F. were run on five panels. See Report 56-560 (attached).

The hours allotted for this test did not permit other tests scheduled to be carried out under this authorization.

FIELD TRIAL:

Rocket blast heat barriers were installed on a spin test airplane under supervision of R. W. Jenkins on 25 January 1957. The laminates were five by fifteen feet by one tenth inches thick. The composition was 181 Velan A glass cloth, epoxy wing to laminate bond, and polyester with antimony trioxide and chlorowax fillers for the heat barrier. The wet layup was installed with contact pressure and rub down. The cure was one day without heat followed by forced curing for eight hours with heat lamps giving temperatures from 120° to 150°F. The airplane has been successfully test flown and spun a number of times.

CONCURRENT TESTS:

Prior to the conclusion of this initial test program, a number of separate tests became necessary because of urgent immediate applications. The data contained in these Test Reports is adopted as a part of this report.

Report No. 56-241 - Qualification Test for Laminates of Fiberglas Cloth No. 181 - Fabricated with Polyite 8000, 20 July 1956.

Report No. 56-329 - Qualification Test for Laminates of Fiberglas Cloth No. 120 - Fabricated with Polyite 8000, 15 August 1956.

Report No. 56-560 (7E596) - Adhesives-Room Temperature Cure for Bonding Polyester and Silicone glass laminate to Aluminum, 18 December 1956.

Report No.56-840 - Qualification Test for Laminates of 181 Velan A Glass Fabric Fabricated with Selectron 50 lb. Polyester Resin, 31 January 1957.

Report No. 56-793 - Skin Panel Evaluations Damping Characteristics, Development of Test Procedures, 6 February 1957.

Report No. 56-884 - Skin Panel Evaluations Fuselage Skin, Model 22, Convair Development Specimens, Damping Characteristics Determination, 11 February 1957.

DISCUSSION OF PROCEDURE:

The basic requirement of resins for the uses considered is good adhesion to metal surfaces and to glass cloth. It should have good internal (cohesive) strength.

When plastic laminates are bonded to metal sheet of given dimensions, resonance characteristics are altered both by the added mass and by the increase in stiffness. On an airframe added mass must pay its way. In addition to improvements in dampening characteristics due to changes in structural properties, we hope for an added improvement due to absorption of energy by the resin. We believe that some flexibility will be a desirable characteristic. This opinion is based on the possibility of using up part of the kinetic energy in a flexed plate to heat the resin.

Protection of metal surfaces requires material which will not crack readily in service. We assume that a desirable general characteristic of resins used for thermal barriers will be the retention of strength at elevated temperatures. The use of resins as sacrifice material, however, will sometimes be justified.

Peel strength is affected by three variables—directly by adhesion and cohesion and inversely by hardness. For this test we have tentatively assumed it to be a first order equation in the general form:

$$P = KAC/H$$

Where P is the measured peel strength per unit width, A the adhesive strength per unit area, C the cohesive strength per unit area, K an unknown constant, and H the hardness.

Peel strength in itself in the absence of other data is not conclusive evidence of the quality of an adhesive. A very low peel strength, however, is inconsistent with the properties desired in resins for uses described in this test. It is therefore a good initial screening test.

Bending over a conical mandrel is an exceedingly severe test of the ability of the laminate to withstand flexing.

DISCUSSION OF RESULTS:

The adhesive resins are usually very long chain polymers of high molecular weights. The general structures of common monomers indicated as follows:

R-CH-CH-R' (with O bridging the two CH)	Epoxy
R-CO-O-R'	Ester
R-NH-CO-R'	Amide

DISCUSSION OF RESULTS: (Continued)

R-S -R'	Sulfide
R-CH(COOH)-NH-R'	Amine
R-NH-O-CO-R'	Urethane

Extensive cross linking of the chains results in a very hard, brittle resin. Excessive cross linking may be blocked by compounding a resin with a large number of groups available for cross linking with resins which have few such groups. Thus the epoxies in Table I, which are hard and brittle, are compounded with softer polyamides and polysulfides to secure the desired properties.

There are practical limits to compounding within the aircraft industry. The physical properties of resins are affected by many other factors such as the lengths and groups in the side chains. Resin manufacturers are not inclined as a rule to reveal the raw materials and proportions used in their products. Tests to determine the suitability of each product offered are necessary.

Exercise caution in using the data in Table II. It is not a reliable measurement of the quality of adhesive formulations in the absence of other data. See Report No. 56-560 (attached) for tensile shear and peel strengths and puffer box tests at -65°F., 80°F., and 180°F. on two of these adhesives.

The epoxies in this test show good adhesion to metal. These resins, however, must be modified to reduce their brittle characteristics for uses where flexibility is desirable.

Of the polyesters only Plaskon 9500 gave an acceptable performance.

There were no humidity tests in this series.

Primer EC 1293 gave good results with epoxies, poor results with polyesters. Plaskon 9500 was satisfactory without EC 1293 and entirely unsatisfactory when used with it.

Visual examination of panels subjected to cycling in the puffer box disclosed no failures. Bending on the conical mandrel and peel testing disclosed no significant change.

Additional data for which need is anticipated in connection with the possible uses outlined in this report are:

(a) Adhesive and cohesive strength through the range of service temperatures anticipated (from tensile shear data).

(b) The brittle point (°F.).

DISCUSSION OF RESULTS: (Continued)

(c) Temperature at which degradation on decomposition occurs.

(d) Hardness curve (-65°F. to 216°F.).

(e) Effect of accelerated weathering.

(f) Effect of accelerated erosion.

(g) Kindling temperature.

NOTE: This report was prepared from data recorded in Engineering Test Laboratory Record Book No. 943.

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TABLE I

COMPOSITION OF TEST PANELS

PANEL No	GLASS FABRIC	No of Plies	Epoxy Resins: Epon 828	Epoxy Resins: Epocast II	Epoxy Resins: EC1472 (3M Co)	Epon 1001	Polyester Resins: Paraplex P-43	Polyester Resins: Paraplex P-444	Polyester Resins: Polylite 8000	Polyester Resins: Laminac 4123	Polyester Resins: Plaskon 9520	Polyamide Resin LP-3	Polyamide Resins: Versamid 125	Polyamide Resins: EC1473 (3M Co)	Polyurethane No 1214	Phenolic Conolon 506-B	Catalysts: Diethylene Triamine	Catalysts: HN 951	Catalysts: A.P. 1330	Catalysts: MEK Peroxide	Catalysts: Cobalt Naphthenate	Catalysts: Curing Agent Z	Primer
			Room Temperature Cure - 7 days																				
1	181-Volan	2	100														8						
2	"	2	100									50					8						
3	"	2	50										100										
4	"	2	100									50	50				8						
5	"	2	100									50	50										
6	"	2	100															10					
7	"	2	100									50						10					
8	"	2	50										100										
9	"	2	100									50	50					10					
10	"	2	100									50	50										
11	"	2					100													2	1		
12	"	2							100											2	1		
13	"	2								100										2	1		
14	"	2									100									2	1		
15	"	2													100				2				
16	"	2	100															10					EC1272
17	"	2									110									2	1		EC1272
18	"	2							100											2	1		EC1273
19	"	2		100														10					EC1272
20	"	2						80 (Plus 20 p... styrene monomer)												2	1		EC1273
21	"	2	100									50	100										EC1273
22	"	2			100									100									
							Heat cure: 34[illegible]°-350[illegible], 14 psi pressure, 30 min																
23	"	2	100																			20	
24	"	2	100										50									20	
25	"	2	100																			[illegible]	
26	"	2	100										25									20	
27	R[illegible]	2				100 (Plus 4 parts dicyandiamide - All [illegible] pre-im[illegible])																	
28	"	2														10 ([illegible] unk[illegible])							
29	181-Volan	2	100									50				(Plus MEK 10 parts)						[illegible]	
30	"	2	100									100											
31	"	2	100										100									[illegible]	
32	"	2	100									10	100										

Note 1: Glass fab[illegible] laminat[illegible] [illegible] x [illegible] x [illegible] [illegible] 5-T6 P[illegible] A[illegible]

Note 2: T[illegible] per Mil-A [illegible] (A[illegible])

Note 3: Gl[illegible] Mil-F-9[illegible]

Note 4: F[illegible]

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TABLE II

Panel No	Conical Mandrel Spec. No	Compression Bend	Expansion Bend	Peel Strength (Drum) (Lbs/inch width) Spec.		
1	A	Damaged	Delamination	J	< 5 Lbs	
	B		"	K	"	
	F	Damaged	"	L	"	
2	A	Slight Damage	Fab. Fail + Delam.	J	10	
	B	" "	" " "	K	8	
	D	" "	" " "	L	8	
3	A	OK	Fabric Failure	J	30	
	E	OK	" "	K	25	
				L	25	
4	A	OK	Delamination	J	11	
	E	Slight Damage	Fabric Failure	K	11	
	F	" "	" "	L	11	
5	A	" "	" "	J	17	
	D	OK	" "	K	19	
	F	Slight Damage	" "	L	17	
6	A	Delamination	Delamination	J	<5#	After cycling in puffer box
	D	Damaged	"	K	<5#	K 12 Lbs
	F	"	"	L	<5#	L 10 Lbs
7	A	"	Fabric Failure	J	12.6	
	D	"	" "	K	10.5	
				L	9.5	
8	A	OK	OK	J	19	
	E	OK	OK	K	25	
				L	21	

TABLE II (continued)

Panel No	Spec	Conical Mandrel Compression Bend	Conical Mandrel Expansion Bend	Peel Spec	Peel Strength (Drum) (Lbs/inch width)	
9	B	OK	Fabric Failure	J	20 Lbs	(Failure 50% Plastic to Metal)
	D	OK	" "	K	20	After cycling in puffer box
	F	OK	" "	L	20	22 Lbs, 22 Lbs, 20 Lbs.
10	A	OK	" "	J	26	(Failure 100% plastic to fiberglas)
	D	OK	" "	K	18	" 50%
	F	OK	" "	L	16	" 30%
11	A	Damaged	Delamination	J	<5*	
	E	"	"	K	"	
				L	"	
12	A	"	"	J	"	After cycling in puffer box
	E	"	"	K	"	5 Lbs
				L	"	
13	A	Delamination	Delamination	J	"	
	D	Damaged	"	K	"	
	F	"	"	L	"	
14	A	Metal Failed	Feb. Fail. + Delam	J	9	After cycling in puffer box
	B	" "	" " "	K	9	9 Lbs
	D	" "	" " "	L	9	
15	B	Slight Damage	Fabric Failure	J	13	
	E	" "	" "	L	13	
16	A	Damaged	Delamination	J	19	
	D	OK	Fabric Failure	K	8	
	F	OK	" "	L	8	
17	A	Damaged	Delamination	J	5	
	D	"	"	K	5	
	F	"	OK	L	5	

TABLE II (continued) TN 56-309

Panel No.	Conical Mandrel Spec.	Compression Bend	Expansion Bend	Peel Strength (Drum) (Lbs/inch width) Spec.		
18	A	Delamination	O.K.	J		
	D	"	O.K.	K	Not Measurable	
	F	"	O.K.	L		
19	A	O.K.	Fabric Failure	J	15	
	D	Damaged	Delamination	K	16	
	F	"	O.K			
20	A	Damaged	O.K	J		
	D	Slight Damage	O.K	K	Not Measurable	
	F	Delaminated	O.K.	L		
21	A	Slight Damage	Fabric Failure	J	19	
	D	" "	" "	K	17	
	F	" "	" "	L	16	
22	1	Slight Damage	" "	3	17.5	Cycled in puffer box
	2	" "	" "	4	20	See Report No 56-560
				5	13	
				6	16	
23	A	Damaged	Delamination	J	6	(Failure 100% plastic to fiberglas)
	D	O.K.	"	K	8	
	E	Damaged	"	L	6	
24	A	Slight Damage	Delamination	J	12	
	D	OK	"	K	11	
	F	OK	"			
25	A	OK	Fabric Failure	K	42	(Failure 95% plastic to fiberglas)
	D	OK	" "	L	35	
	E	OK	" "			

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TABLE II (continued)

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Panel No	Spec	Conical Mandrel Compression Bend	Conical Mandrel Expansion Bend	Peel Strength Spec	Peel Strength (Lbs/inch width)
26	A	Slight Damage	Delamination	J	No valid measurements - Fabric breaks at about 16-17 Lbs
	E	" "	"	K	
				L	
27	A	O.K.	"	J	14 Lbs
	D	O.K.	"	K	No measurements - Fabric brittle
	F	O.K.	"	L	
28	A	Slight Damage	"	J	9 Lbs.
	D	Damaged	"	K	Material too brittle for peel tests
	F	"	"	L	
29	A	"	"	J	" " " " " "
	D	"	"	K	
	F	"	"	L	
30	A	OK	Slight Damage	J	good adhesion to metal - Failure could not be started for peel test.
	D	OK	Damaged	K	
	F	OK	"	L	
31	A	OK	"		
	D	O.K	Delamination	K	28
	F	O.K	"	L	28
32	A	O.K.	OK.	J	17
	D	O.K	Slight Damage	K	18
	F	O.K.	" "	L	19